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FREDERICK J. H. MERRILL *Director*

Bulletin 48 December 1901

PLEISTOCENE GEOLOGY
OF PORTIONS OF
NASSAU COUNTY AND BOROUGH OF QUEENS

BY JAY BACKUS WOODWORTH B.S.

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PREFACE

The following report by Prof. Woodworth on the results of field work in western Long Island is in continuation of an investigation of the quaternary formations of Long Island and the Quaternary history of the Hudson river valley begun in 1883 by the present state geologist.

The great development of the branch of Quaternary investigation makes it now possible to seek positive proof where formerly only broad inferences could be drawn.

Prof. Woodworth's work will include the Hudson and Champlain valleys and the drainage basins tributary to them and his results may be expected to contribute an important chapter to American Quaternary history.

FREDERICK J. H. MERRILL
State geologist

INTRODUCTION

The term Pleistocene is used here as the equivalent of Quaternary, a term which has heretofore been employed in the museum reports for the period of great ice sheets.

The Oyster Bay and Hempstead quadrangles together include a belt about 13 miles wide extending north and south across Long Island. The area thus mapped comprises, aside from a triangular area on the mainland about Mamaroneck not dealt with in this report, the major portion of the towns of Oyster Bay, North Hempstead, and Hempstead, the coast of Long Island sound from Manhasset bay on the west to Oyster Bay harbor on the east, and the Atlantic shore from the eastern part of Far Rockaway beach, eastward to Short beach.

The matters considered in this report are 1) the topography, 2) glacial deposits, 3) Pleistocene history, including data gathered from the area on the west, 4) the post-glacial changes and processes now in action.

TOPOGRAPHY

As the traveler from Greenport or Sag Harbor approaches the western end of Long Island, there are more or less continuously before him two low ridges, one skirting the north shore of the island, the other less elevated and continuous and at a variable distance inland from the south shore, the two being separated first by the deep embayments of the pronglike eastern end of the island, and then by a broad, sandy plain, narrowing westward to the eastern limits of the area with which this report is concerned. At this point, near Syosset, the north and south ridges rudely coalesce. The northern ridge takes a south southwesterly course, lies more remote from the shore of the sound, and traverses the area so as to inclose the southern ends of the V-shaped harbors of Manhasset and Great Neck bays.

What appears to be a continuation of the southern ridge is traceable as a series of low mounds at Locust Grove, Jericho, thence south of Old Westbury, at Albertson station, Searington, and so westward to an abrupt termination at the base of the higher, more massive northern ridge just east of Lake Surprise. Between these mounds

and the northern ridge rude plains of coarse gravels rise gently toward the southern face of the latter. Between the mounds themselves, these plains merge southward into a broad, slightly creased plain, which sinks to the level of the marshes and the sea on the south coast.

The main ridge rises very frequently to a hight of 300 feet above sealevel, and from 100 to 150 feet above the low ground at its base. Where most distinct in its topographic features, its base is but little more than a mile wide. Between Syosset on the south and East Norwich and Brookville on the north side, this ridge is relatively low and narrow. Between Jericho and Wheatley three or four well marked spurs extend for one or two miles to the southward, impinging on the line of mounds representing the continuation of the southern ridge above described. West of this broad development, the ridge becomes more massive and elevated, attaining its highest point in Harbor hill 391 feet. West of Roslyn, it gradually falls off in elevation, and from Lake Surprise westward becomes a low, flat ridge with a steep southerly front and with a gentle slope northward. The broad crest, seldom over 200 feet above the sea, is cast into mounds and hollows, or knobs and basins, some of the latter containing small tarns or lily ponds, a feature less common in the eastern extension of the ridge.

From the northern base of the ridge there extends a series of plains or terraces, frequently at an elevation of about 200 feet near the ridge, separated by the wedge-shaped harbors of the north shore. These surfaces form the headlands or "necks," between the bays, with elevations of from 100 feet to nearly 200 feet. The surface is deeply indented by valleys mouthing on the broader indentations of the coast line; and in the vicinity of Oyster Bay harbor the land is reduced to a few islands, now tied to the main island by marine beaches.

Between these rude plains on the north and the broad plain on the south the deeper reentrants of the northern coast are continued by narrow depressions across the main ridge. One of these troughs occurs south of Manhasset, another at Roslyn, and similar passes traverse the ridge at the eastern base of the Harbor hill mass, on the road from Brookville to Locust Grove, and eastward along the

line of the highways connecting Syosset with towns on the northern side of the ridge.

The northern plains varying from 190 to 220 feet in elevation are well developed about East Norwich. Their surface is roughened and is usually more uneven than the 20 foot contours of the accompanying map can be made to indicate. These upper plains frequently overlook like a terrace lower levels of much more uneven surface near the 100 foot level, as between Manhasset hill and Flower hill, between Greenville station and Glenwood landing, and on the borders of Mill Neck creek. The terraciform slopes are like the sides of those valleys which dissect the rude plains, usually irregular, roughly lobate or cuspate, and sloping without sharp demarcation into the lower grounds which they overlook. The northern margin of these dissected plains often reveals them as mere narrow ridges with rounded summits, and with small bays or marshes on either side, as at Mill Neck.

The broad southern plain needs little more description beyond that already given than to note a low ridge, about 20 feet in elevation and from a mile to 2 miles wide, springing out from the plain near Lynbrook, and extending southwestward parallel to the main ridge farther north, till it is cut off by the sea at Far Rockaway. Associated with this ridge is the semicircular depression on the west known as Jamaica bay, largely marsh-filled, and an extension of this feature in the region of Broad channel. Along both north and south shores are bars and beaches, with cliffs, produced by the recent work of the sea.

A summarized view of the island in this region would be fairly represented in a cross-section, such as that shown in fig. 1, in which the northern, rude, terraced plains rising rather abruptly above the sound are succeeded on the south by the main ridge and the outlying knobs, from which there stretches a broad plain sloping southward to the sea or confronted near Far Rockaway by a low ridge, beyond which in turn lie the south beaches.

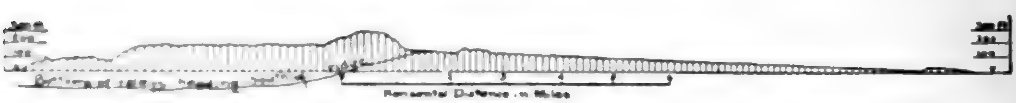

Fig. 1 Diagrammatic cross-section of Long Island near the boundary line of Queens and Nassau counties

The main topographic features thus set forth are traceable eastward for 200 miles, one or more elements appearing either on the islands off the south coast of New England or on the adjacent mainland, the essential elements of the topography being two ridges each one of which rises rather abruptly above a plain sloping southward from it toward the sea. If the plain is absent, the sea covers the space where we should expect it to occur. Westward, the main ridge here described abuts on lower New York bay at the Narrows, reappearing on Staten Island and continuing to be recognizable far inland over the continent as a topographic feature, often imposed on the rocky profile of valleys and high ridges alike.

GEOLOGY

The topographic features above described have long been known to constitute a group of drift materials laid down along the margin of an ice sheet or a successive series of such glaciers in the Quaternary or, as it is now usually denominated, the Pleistocene period, a time defined as beginning in this hemisphere with the first of these ice invasions on the coast plain and closing with the final disappearance of the ice from eastern America. The time since this disappearance of the ice, variously estimated at from 7000 to 10,000 years, is frequently denominated the post-glacial epoch. With the deposits made during this Pleistocene period, the present report has mainly to do.

Pre-Pleistocene formations

The basement on which these Pleistocene drift materials repose in this part of Long Island has but a small exposure above sealevel, and that is mainly limited to the northern coast north of the main ridge, or moraine. These older materials are clays and sands, evidently an eastward extension of the nearly horizontal clays and sands largely of Cretaceous and late Jurassic age which constitute a large part of the coastal plain from New Jersey southward. Little is known of the attitude of these beds in this region, prior to the earliest ice invasion, farther than the reasonable presumption that they lapped over on the underlying gneisses and igneous rocks of the mainland and the extreme western end of the island, gently sloping from their inner margin seaward, as they still do in the coastal plain south of the glacial district.

The fact that, wherever these older clays are now seen in the cliffs and exposures about the north shore of Long Island, they are involved in folds and disturbances with the earlier glacial gravels and sands is evidence that they have been disturbed during Pleistocene time by the same agency which produced dislocations in the earlier glacial deposits. Since they have been thus displaced, their present relief can not be taken as evidence of the form of the land surface on which the glacial deposits were laid down. It is even uncertain whether the depression known as Long Island sound had any existence prior to the disturbances in which these clays were involved in Pleistocene time. Everywhere the existing relief of these clay masses above sealevel is a function of their displacement. The entire absence of any relatively hard or resistant layer in the series makes it even doubtful if the seaward migrating outcrops of the Cretaceous series presented at the time of the first ice invasion, anywhere along the line from Cape Cod or Nantucket westward to New Jersey, anything like a bluff or inface of strata overlooking the bared, hard rock terrane on the north, such as might be expected were the rocks of a firmer character or of greater lithologic variety. At most, where these older clays now rise highest in dislocated masses, it may be that remnants of the old coastal plain, similar in origin to the highlands of Navesink on the New Jersey coast, stood up on the interstream areas. The deep reentrants of the northern coast, as in the case of Hempstead bay, appear to be features of Pleistocene date, across whose site the Cretaceous clays previously extended unbroken. In short, no definite trace of an older detail of land surface is now discernible beneath the glacial materials within the limits of this report. The absence, however, of deposits intermediate in date between the older Pleistocene and the ancient clays warrants the supposition that at least the northern part of the island was an area of erosion by ordinary meteoric agencies.

Beneath the Cretaceous and Potomac clays should come the hard rocks exposed on the mainland. These hard rocks in the form of gneiss appear at the surface westward in Long Island City and have been met in borings in Brooklyn. The precise depth at which they occur beneath this area is at present a matter of conjecture.

The entire absence of hard rocks in fixed ledges or outcrops within

the limits of this part of the island naturally precludes any observation of glacial striae indicating the direction of local ice movement. The ledges of gneiss in Long Island City bear striae whose direction is s. s. e. and presumably a similar course was followed over this tract.

Glacial formations

The glacial formations of this area are divisible into two great groups: those of an unassorted, unstratified structure, composed of mixtures of boulders, pebbles, sand and clay, frequently, when covering the surface, with a knob and basin topography, forming in general terms till, or boulder clay when boulders are mixed with clay; and those composed of gravels and sand with a stratified structure showing their evident deposition by running water.

Till constitutes the larger part of the ridges or moraines already described. Boulder clay occurs as a thin layer in the bluffs on either side of Hempstead harbor and in the area between Searington and the main ridge near Lake Surprise. Ordinary till, largely in the form of scattered boulders, covers the terraced plains and the ridges and valleys north of the main moraine. The rest of the area is largely composed of gravel and sand with local deposits of blackish or bluish black clay not certainly of glacial origin and perhaps to be regarded as of Tertiary or older age. Gravel and sand constitute by far the greater portion of the glacial deposits both as regards the surficial extent and cubic contents of the Pleistocene.

Since these deposits appear by their structure and relations to have been deposited in succession, some till having been made under the ice or at the ice front while gravels and sands were being laid down by water running through or pouring out of the ice, it will be necessary to consider them in the order of their development in time. In the chronologic succession, the glacial deposits exhibit three marked phases of Pleistocene history in this area: 1) a group of older gravels and sands with an intercalated till bed, the evident equivalent of the Columbia formation; 2) the moraines and their attendant stratified gravels and sands, forming the topographic details of the surface; 3) between these deposits in the order of time, evidences of erosion by other than glacial action, which demand separate treatment.

Columbia formation. The rude terraced plains lying north of the main moraine on the Oyster Bay quadrangle are but the surface of a thick series of gravels and sands on which the moraines have been heaped. The reasons for referring to them heretofore as older Pleistocene may now be set forth, together with the evidence in favor of referring them to the Columbia formation of McGee,[1] the group to which the deposits appear to have been referred by that author in 1888.

F. J. H. Merrill, following the pioneer work of Mather, pointed out in 1886 that these gravels and sands under the name of "gravel drift" underlie unconformably the moraine, and concluded that they were deposited by swift currents carrying along fine and coarse materials together.[2]

The deposits as exposed on the Oyster Bay quadrangle consist of water-worn gravels and sands, clearly divisible in certain sections into an upper and lower series by a thin bed of glacial boulder clay. It has not been possible in the course of the present survey within the area to determine whether or not the group thus defined is to be divided into an earlier dislocated and a later undisturbed series, but it is clear that many sections of these gravels, along with what appears to be the boulder bed named, have been dislocated along the north coast of the island. On Marthas Vineyard and Block island such a division has been made out,[3] but the boulder clay parting, on the other hand, has not been found there in the position of an intermediate conformable bed.

The gravels consist of water-worn fragments of quartz derived from veins, granite and gneiss from the ancient Piedmont terrane of the mainland, of silicified fossils from the metamorphic Paleozoic limestones of the mainland, cherts of the same origin, and ferruginous sandstones and fragments of concretions from the underlying Cretaceous or Potomac section.

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[1] McGee, W J. Three formations of the middle Atlantic slope. Am. jour. sci. Ser. 3. 1888. 35 : 367–88, 448–66. It has not seemed possible at present to establish a satisfactory comparison of the deposits in this portion of Long Island with the formations recognized in New Jersey by Prof. Salisbury.

[2] Merrill, F. J. H. N. Y. acad. sci. Annals. 1886. 3 : 341–64.

[3] Woodworth, J. B. Unconformities on Marthas Vineyard and Block island. Geol. soc. Am. Bul. 1897. 8 : 204–11.

Quartz pebbles predominate in this formation, particularly those stained yellow by the oxid of iron; hence the term, "yellow gravel," which has been sometimes given to it. This discoloration will be treated more at length later. White quartz pebbles are not uncommon, pebbles which appear never to have been stained. The silicified fossils and cherts are relatively rare, but search carried over a few square yards of surface in any gravel pit in the formation north of the moraine will usually reveal two or three of these erratics. The gneissic and granitic pebbles are at least in the mass of the formation not much decayed. On the whole, the materials are like those in the moraine and in the gravel and sand terraces on the mainland except for local staining by iron oxids. The comparison with the moraines is perhaps hardly just, because the moraines are locally largely composed of rearranged drift from these same beds, as in Harbor hill. The inference from the sands and gravels is that they are of glacial origin, modified by the work of running water, either ice-born streams or extraglacial waters. This conclusion as to their glacial origin amounts to a certainty when the intermediate boulder clay bed is taken into the account.

That the beds extend southward beyond the Harbor hill ridge or moraine can hardly be questioned; but it is difficult to distinguish the formation in front of the moraines from the later gravels and sands washed out from the ice front. At one point in the mounded drift southwest of Roslyn an exposure by the roadside of a coarse cobble bed with yellow pebbles contains also iron stone concretions which have evidently not been rolled, showing that they are probably in place, though loosened by exposure to surface actions from the surrounding pebbles. Beds of this character are found at the base of the Pleistocene on Marthas Vineyard in the Gay head section,[1] where the origin of the concretions is clear. The concretions arise from the erosion of light colored clays of the underlying Cretaceous or Potomac beds and their deposition with the coarse gravels as pebbles permeable to percolating water charged with iron salts. Cementation takes place by deposition of iron oxids around all of the pebbles, involving the outer part of the clay

[1] Woodworth, J. B. Geol. soc. Am. Bul. 1897. 8 : 205–6.

pebbles, which becomes converted into a hard stone layer, the inside remaining usually unconsolidated. When in after time these nodules are wrested from the bed in which they originate, they are broken open, the clayey or sometimes sandy interior washes out and there is left a potlike, hollow pebble of the kind known as aetites or eaglestone.[1] Hundreds of these nodules were dragged out of their bedding places by the advance of the ice over the Columbia at the time of making the terminal moraine on Marthas Vineyard and in portions of Long Island.

The occurrence of these nodules at the locality mentioned affords evidence that the underlying white clays and sandy clays were eroded at the beginning of Columbia deposition. The unconformity thus inferred is widespread to the east on Marthas Vineyard and Block island and along the Atlantic coast southward to the vicinity of Washington. Of direct local evidence, little can be said. On the shore north of Coldspring the gravelly beds at the base of the tilted Pleistocene series may be seen resting on the Cretaceous and older clays, but there is no observed difference of dip, though the absence of identifiable Eocene or Neocene beds is proof of an unconformity. No clearer fact than this was gathered from the similar sections about Glen Cove and Glenwood.

Aside from this unmistakable instance of older gravels lying outside of the moraine, it is uncertain to what extent the older beds make up the frontal plain. Yellowish gravels abound in the road and railroad cuts, but the yellow quartz pebbles have invariably been washed and worn since they were stained, and similar pebbles are now working their way from the cliffs down the beach slopes into the deposits now making along the coast. It is to be inferred, however, from the attitude and thickness of the Columbia north of the moraine that a large part of the section south of the moraine is composed of these beds.

The structure of these beds is revealed in only a few pits and coastal sections. The most extensive exposures in 1900 were found in a number of sand pits on the west shore of Hempstead harbor. In these pits the beds are horizontal, and the boulder clay bed is clearly traceable.

[1] Geikie, A. Textbook of geology. 3d ed. 1893. p. 146–47.

Plate 2

H. Ries, photo.

View showing boulder bed and some of the stratified sands and overlying gravel, King's pit, Hempstead Harbor

A borrow-pit in the southwestern part of the village of Oyster Bay showed beds dipping southward 26°, an angle not far from that of fore-set beds in delta structure. These beds were overlain by other sands in horizontal beds, and the whole appears to be a portion of the normal section of the lower part of the series. This section lies between 40 feet and 50 feet above sealevel. There is nothing in the attitude of the beds at this locality to indicate that the strata were disturbed after deposition, as is the case on the contrary in so many of the bluffs along the north shore. Another good exposure occurs in Cooper bluff between Oyster Bay and Coldspring harbors, in the cliff on the south side of Oak neck near the wharf, and at Barker point.

The boulder clay bed. In many of the coastal sections on the north shore an unstratified mixture of pebbles, sand and clay in a bed varying from 3 to 10 feet in thickness may be seen in a position to indicate that it is interstratified with these older gravels; but it is only in the sand pits on Hempstead bay that a bed of this character is fully revealed. About half way up the bluff, or about 100 feet above the bay, there is a bed of boulder clay from 2 to 3 feet thick, traceable in all the pits open in 1900 south of Bar beach. The matrix of this bed is an unctuous dark blue clay locally sandy or gravelly. Scattered through it and sometimes in close contact with each other are glaciated boulders often over 1 foot in diameter and numerous pebbles attesting the glacial origin of the deposit. Several large boulders examined in 1901 by Dr F. J. H. Merrill and the writer were recognized by the first named as having been transported in all probability from the Adirondacks. Other small boulders carrying Silurian fossils indicated their origin in the Hudson valley north of the Highlands. The longest journey made by these materials appears to exceed 200 miles.[1]

The bed rests evenly and smoothly on the underlying gravelly sands without marked disturbance or erosion. This relation to the underlying bed suggests the dropping of stones and clay from overlying floating ice more than the actual advance of an ice sheet on this part

[1] Mather reported finding in the valley of Schoharie kill, boulders with "opalescent feldspar like that of Essex county" and referred them to parent ledges in the eastern Adirondacks. Geol. rep't. 1843. p. 187.

of the area of the Oyster Bay quadrangle at this time. The thinness of the bed, and the identity of the sediments which underlie and succeed it, go far to show that this boulder clay making was but an episode in the formation of the gravels and sands in this field.

The outcrop of the boulder clay bed on the bluffs gives rise to boulders which have slidden down the slope. A section transverse to the face of the bluff in one of the pits showed an ancient talus of boulder clay extending down to the road. Not only the texture and structure of the sands and gravels, but also the appearance of the boulder clay bed in these pits indicates that these deposits extended eastward across what is now the bay to the like deposits on the opposite bluff. Nowhere do the deposits show that increasing coarseness toward their exposed edges which is the characteristic mark of the heads of glacial sand plains and those bodies of glacial sands and gravels which have accumulated about the edge of a glacier or its outlying stagnant masses. The bays are clearly valleys of erosion cutting through both the Pleistocene and locally the pre-Pleistocene clays and sands alike.

A bed of till, presumably an extension of that above described, occurs on the east shore of Hempstead bay in Glen Cove about 60 feet above sealevel, in the following incompletely exposed section.

PLEISTOCENE SECTION IN GLEN COVE, FROM TOP

Gravel and fine sand	3 ft	
Till, with small angular boulders	5	
Gravel, clayey	1	6 in.
Gravel, sandy	3	
Sand, base not seen	3	

20 feet distant the till passes into stratified gravel and sand. The rapid transition of the till into stratified drift at this locality explains the absence of the bed in many sections. It was probably locally deposited.

A similar till bed distinctly less bouldery but equally amorphous, is exposed in the bluff at Barker point, from which, first appearing at about 20 feet above the sealevel, it sinks, on the western face of this headland, southward, being involved in the dislocations of the north coast of the island (fig. 2).

Plate 3

H. Ries, photo.

King's sand bank, Hempstead Harbor, showing boulder bed between glacial gravels and sands. The boulders piled in foreground have been taken from this bed.

A small exposure of a bed of till also existed in the summer of 1900 near Rocky point at the northwestern extremity of the so-called Center island in Oyster bay. The annexed sketches illustrate the varying conditions seen at this locality. In fig. 3 the beds in the bluff west of Rocky point show again the transition from till to stratified beds. A detail of the western part of the section is given in fig. 4, showing loesslike sands at top, inclosing boulders, beneath which comes a bed of gravelly sand from 6 to 10 feet thick, with pockets of clay. A gravelly till 10 feet thick underlies this bed, below which again appear compound gravels and sand. Near the headland underlying blue clays rise up in a knob, with sands cut off on the east, the whole being overlain unconformably by till with boulders up to 2 feet in diameter. At the headland on the southwest, the sections shown in fig. 5 and 6 exhibit an earthy gravel (as in fig. 6) evidently a phase of the till bed or the till as in fig. 5, resting unconformably on tilted yellow sands, which in turn repose on disturbed clays.

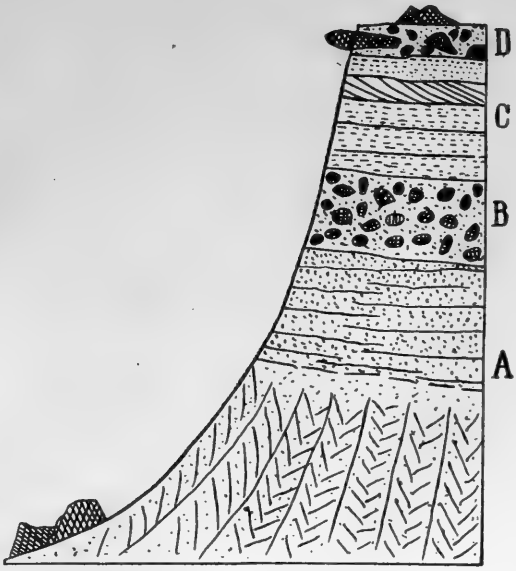

Fig. 2 Southwestern face of Barker point. A, cross-bedded ferruginous sands; B, the till bed 5 or 6 feet thick, resting unconformably on the sands, and overlain by sands; C, sands; D, surface till and boulders, the fine materials being largely rearranged sands

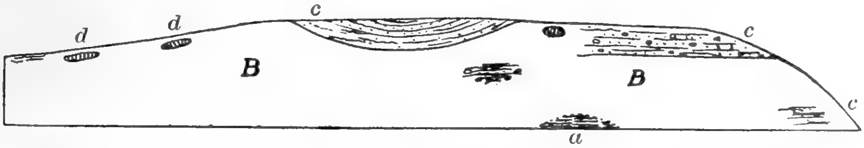

Fig. 3 Section along the bluff west of Rocky point. *a*, clay exposure· B, till; *c*, sands and gravels; *d*, partially buried surface boulders

Above these exposures on the shore the ground rises on the eroded and till-covered slopes of the Columbia. The evidence of unconformity between the till bed and the underlying disturbed clays and sands is in sharp contrast with the sections on Hempstead bay and

admits a different interpretation, one favoring the dislocation of the section before the deposition of the till but on a scale quite admissible as the work of a glacier. The dislocated beds dip at high angles to the south. The underlying blue clays weather whitish, carry quartz pebbles and slight traces of black carbonized plant remains and are presumably Potomac or Cretaceous. They are unconformably beneath the sands.

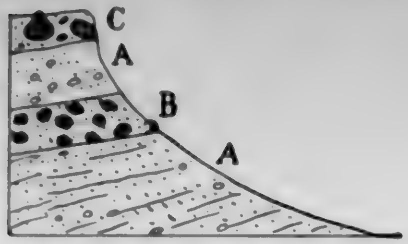

Fig. 4 Detail of section just west of preceding section. A, sands and gravels; B, till; C, loesslike sands inclosing boulders

Another dislocated section affecting sands underlain by clays occurs at the southern end of Center island (fig. 7). The clays are here dark blue, well laminated, and pass by gradations into the overlying sands, recalling many sections on Cape Cod bay in Massachusetts. The upper part of the sands carries boulders; the whole may well be a basal portion of the Columbia. At one point a small fold overturned southward has passed into a reverse fold-fault. Viewed as an overthrust, the movement has been northward. To accord with the hypothesis of glacial thrust acting from the north, it is necessary to suppose that underthrusting has taken place.

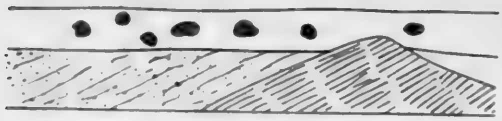

Fig. 5 Local section at Rocky point showing deformed blue clays and banded sands, unconformably overlain by till with boulders up to 2 feet in diameter, passing laterally into stratified gravel

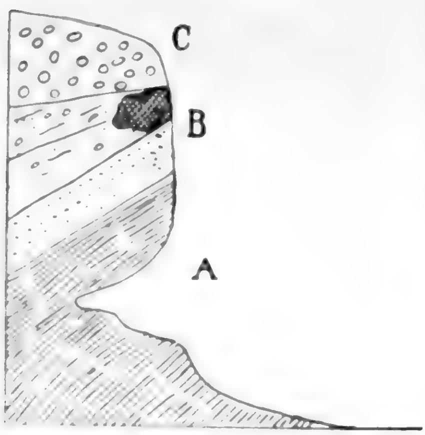

Fig. 6 Section at headland on southwest of Rocky point. A, clay; B, yellowish sandstone, with boulders; C, earthy gravel

The railroad from Oyster Bay to Roslyn passes through three deep cuts in an eastwest valley in Mill Neck. In the cut nearest Oyster Bay, whitish to pinkish sands, probably Cretaceous, appear at the bottom, succeeded by about 30 feet of coarse gravels, ill stratified and

Plate 4

H. Ries, photo.

Near view of boulder bed in King's sand bank, Hempstead Harbor

overlain by at least 20 feet of clayey sands passing above into cleaner sand. These beds dip gently east.

The second cut west shows more of the white sands, dip uncertain, overlain by glacial gravel with small boulders. The third cut west exhibits cross-bedded, white clayey sands, presumably Cretaceous, overlain by 10 or 12 feet of glacial gravels and sands with small boulders. The section shows no dislocation.

In the first of these sections the measured exposure is evidently a part of the Columbia; in the second cut, the glacial gravels mantle the eroded surface of the pre-Pleistocene series, having been deposited subsequently to the deformation and gullying of the beds. These top beds, by their boulders and lack of stratification, as well as their relation to the eroded clays, evidently pertain to the last drift. The sections show, however, that the Columbia mantles over and is wrapped about masses of the pre-Pleistocene series, as previously stated on p. 622. Similar partial sections occur on Great Neck near Manhasset.

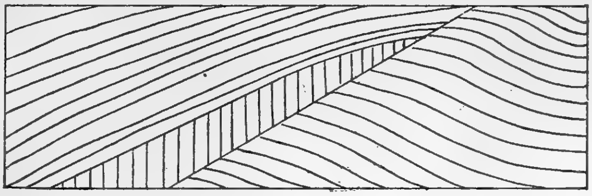

Fig. 7 A fold-fault in clays at southern end of Center island in Oyster Bay harbor

In the sand pits northwest of Port Washington, the pre-Pleistocene clays are also involved in folds, giving rise to a structure, the upper member of which is a gravel and sand bed of the Columbia formation, itself clearly older than the sands of the Port Washington delta yet to be described (p. 646). In this instance the axis of the anticlinal structure lies north and south, and the dislocation may be of a relatively late date, even so late as the time of formation of the delta named, when the ice lay deeply embayed along the north shore of Manhasset neck and when an easterly movement in the mass might be expected, since the ice at this locality was on the eastern margin of a glacial lobe at the mouth of the Hudson valley.

The deposit of sands and fine gravels forming the tabular hillock whose frontage on Manhasset bay near Port Washington is known as Tom point is a unique example of the deformation and erosion of

the Manhasset sands. The deposit, now largely removed for mason's supplies, exhibits a strong flexure with a downthrow to the south. On either side of this flexure the beds are horizontal but those on the north belong stratigraphically below those now on the same level but on the south of the flexure. The annexed cut (fig. 8) as sketched from a photograph exhibits the sand beds in the top of flexure. The truncation of the flexed beds at the present surface is sufficient evidence of the erosion of the whole to its present level. A few small glacial erratics occur on the surface, but the ice sheet appears to have swept over it without leaving other deposits. The top sands have lost their stratification but it is impossible to say how far this disturbance was due to the ice sheet and how much has been done by the growth of plant roots in the subsoil.

The small heads of Cretaceous clay appearing above sealevel on the shore of Manhasset bay, where the older Pleistocene is essentially horizontal, along with the protruding masses of these older clays in the massive portions of the section, indicate a relatively early dislocation of portions of the pre-Pleistocene basement of the island. It would therefore appear that the dislocations were not all of the same date in this portion of the island, ranging in age from at least the oldest Pleistocene to the time of the main moraines, certainly none of them are later than the Port Washington stage.

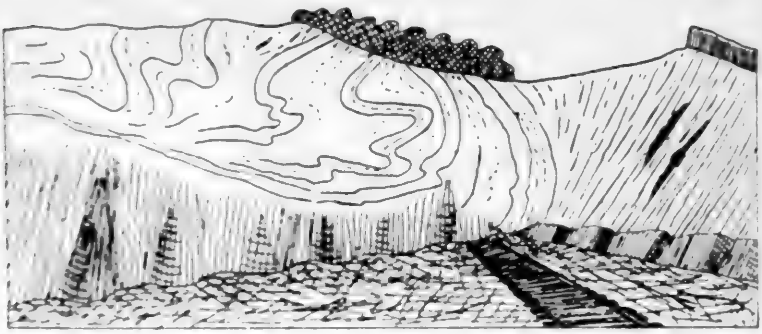

Fig. 8 Southward dipping flexed beds in Manhasset sands at Tom point near Port Washington, showing eroded surface

The upper limit of the Columbia accords roughly with the hight assigned to the plains described as lying north of the inner moraine, that is to say, the deposits are approximately delimited by the 200 foot contour line. Where lower, they have been eroded; where higher surfaces exist, later glacial drift, usually till, is found cover-

Plate 5

H. Ries, photo.

King's sand bank, Hempstead Harbor. Group of boulders which have fallen down from the boulder bed. The latter is seen in upper portion of view and some boulders are to be seen in place.

ing them. If then, we reconstruct the cross-section of the formation, it would appear as a wide belt of gravels and sands declining southward to the sea and rising with a cuestalike bluff from the sound on the north.

In ordinary nonglacial, coastwise beds, such a bluff would indicate the retreat of the beds, extending originally north to an overlap on the mainland, to their present northern limit. But in the case of glacial deposits laid down about the border of an ice sheet, it is highly probable that the beds never thinned out landward to an overlapping series on the ancient gneiss of the region beyond the sound. Somewhat similar glacial gravels and sands of the last ice epoch, on Nantucket, end abruptly on their northern or iceward margins in bluffs overlooking lower ground once occupied by the basal portion of the ice sheet against whose mural front they were laid down.[1] Upham[2] has expressed his belief in the origin of these gravels and sands in this manner, differing only from the view here set forth in that he supposes the beds to be essentially contemporaneous with the moraines which rise above their level.

It is evident that these Columbia beds, exposed in the bluffs and rude terraces along the north coast of the island, may once have extended much farther to the northward, but how much farther into the area of the sound is not now definitely determinable. Their occurrence on the Connecticut mainland has not as yet been reported, and till that area is carefully studied with this problem in mind, it can hardly be satisfactorily settled. The same indefinite answer is elicited from a study of the equivalent beds on Block island and Marthas Vineyard. In other words, the precise position of the ice front and terminal moraine of this earlier ice advance is unknown, though it could not have been many miles north of the inner limit of these gravels and sands with their intercalated bed of true till.

Aside from the disturbances above noted, two classes of changes have affected these beds since their deposition: 1) the discoloration of the beds by local and secular chemical changes in the iron-bear-

[1] Curtis, G. C. & Woodworth, J. B. Jour. geol. Chicago, 1899. 7:226-36.

[2] Upham, Warren. Glacial history of the New England islands. Am. geol. 1899. 24:79-89, with bibliography, p. 89-92.

ing content of the gravels; and, 2) the erosion of valleys and harbors in its mass prior to at least the last till deposits on the island. The latter phenomena are so extensive as to indicate a considerable lapse of time for their production.

Discoloration of the gravels by the yellow or hydrous sesquioxid of iron has taken place to a variable extent, sometimes affecting less than a cubic foot of the materials and in other places, particularly beneath the moraine, changing the entire appearance of the section there exposed.

Local discoloring by the yellow oxid is frequently seen in the gravel pits on the west shore of Hempstead bay, wherever some iron-bearing pebble has oxidized and hydrated, the iron salts spreading outward and mainly downward through the action of infiltrating rain water. The sands and gravels above the till bed mainly exhibit this change.

Widespread discoloration of the gravels to a deep yellow occurs in Roslyn in the bluffs on the east side of the town below the base of the moraine. This deeper and more thorough coating of the gravels in this locality is a natural result of the lixiviation of the ferruginous rocks in the overlying moraine, the products of whose oxidation and hydration have worked downward into the porous gravels beneath.

The discoloration is therefore a change which is probably secular and in progress. That it had already advanced very far before the moraines were formed is indicated by the abundant occurrence in the moraine of yellow, stained quartz pebbles; but these pebbles in the moraine are usually not in the place in which they were originally stained, for they have water-washed surfaces. The staining was accomplished while the pebbles lay in an earlier deposit, either the Columbia or some unexposed member of the ancient coastal plain.

Erosion interval. The evidence of late dislocation on a small scale commensurate with the pushing and dragging action of a great ice sheet, the spreading of till and boulders over the surface of the Columbia, and the amassment of heaps of drift evidently in part derived from the surface of the deposit, afford indubitable evidence of the degradation of the formation to some extent by ice action subsequent to the completion of the series of deposits. But

Plate 6

H. Ries, photo.

Sand washer, King's sand bank, Hempstead Harbor

the surface of the formation north of the moraine is carved into valleys and deep reentrants of the coast line, depressions the main features of which are consonant neither with the southward movement of ice over the area nor the erosive work of subglacial streams discharging across them at the ice front. That these valleys antedate the last ice advance appears to be shown in that all of them are more or less encumbered by morainal materials.

As typical examples of these valleys, that entering into Manhasset bay at Glen Cove, as well as that in whose lower extension Mill Neck creek flows, may be taken. The Glen Cove valley heads at the inner base of the moraine near a very well marked pass at the eastern base of Harbor hill, a passage through which undoubtedly subglacial waters escaped when the ice front lay against the moraine and at a time when it must be admitted subglacial drainage may well have followed the course of this valley for a part or a whole of its course. The objections to accepting the valley, however, as the work of this subglacial stream, aside from those above stated, are 1) the graded character of its bed, sloping northward toward the sea as if made by a normal stream like that now flowing in it, though the existing stream evidently flows in a valley which it found encumbered by more or less glacial drift; 2) the tributary vales evidently cut by running water as in normal open air streams; 3) the course of the stream at Glen Cove, east and west, in a direction contrary to ice movement in this locality. The digitation is even more pronounced in the case of the Mill Neck creek valley just south of the ponds. The upper part of the valley above the 100 foot contour is also walled in by glacial deposits later than the Columbia in which it is cut. Like considerations hold in regard to the deep valleys which extend from Oyster Bay village toward East Norwich. The Mill Neck creek depression continues below sealevel, and, branching south of Oak neck, separates that island — an island except for the barrier beach tying it to the land on the west — from Mill Neck. It is evident that there has been developed a marked dissection of the Columbia, and that this dissection on north and south as well as on east and west lines is increasingly severe toward the northern coast, as in the normal degradation of an area of incoherent materials marginal to a depression such as that of

Long Island sound. The inference is that at a time immediately before the last advance of the ice the area was exposed to ordinary stream action opening out valleys on the gravels and sands, the mouths of these streams reaching the sea below the present sealevel.

There are other evidences, however, which show that ice action has considerably modified and enlarged certain of these valleys. Such enlarged valleys constitute the bays and harbors of the north shore. These harbors have their bottoms 27 feet below sealevel in Hempstead bay, 61 feet in Oyster bay and 33 feet in Manhasset bay. This depth in each case is probably less than the original depth of the depressions, for there has been some infilling by glacial deposition — probably small as judged by the filling in of valleys extending above sealevel — and some infilling through post-glacial deposition by tides and currents. Arguments for the excavation of these embayments subsequent to the formation of the Columbia gravels and sands have already been given on p. 628. Homologous depressions occur eastward on this island in Coldspring and Northport harbors. They are also found on Marthas Vineyard in Lagoon pond and Menemsha pond, and on Block island in Great pond.

As to the period of this valley-making, excepting the modification and enlargement by ice action, it is clearly older than the main or inner moraine at Roslyn, a deposit believed to be equivalent to the Cape Cod moraine. Whether the stream erosion preceded or followed those fragments of an older moraine which on this sheet mark the western extension of the outer or Nantucket moraine, appears to be locally undeterminable, because the two sets of phenomena are not found in association. If a comparison with Marthas Vineyard and Block island holds good, the erosion of the valleys should be here as there anterior to both moraines. In all of these New England islands, the valleys do not occur as such on the south of the moraines, because that area has been buried beneath the outwash plains of the first or outer moraine on the eastern islands and of both the first and second, or inner and outer moraine on Long Island.

The time involved in the excavation of these valleys is indeterminate. They are largely excavated in gravels and sands of a porous structure. Much of the existing rainfall passes through the

deposits where clays do not occur, finding its way out near sealevel in springs, as in the village of Oyster Bay. At best, surface streams would have cut but slowly on these deposits, as they do now, the excavation in post-glacial time being practically nothing in the form of mechanical abrasion.

The share which the ice and the subglacial streams may have had in the excavation of the harbors, is discussed in connection with the moraine on p. 643.

Wisconsin epoch. Moraines and attendant sand plains. The existence of two lines of moraines in this area has already been set forth in the account of the topography. Both of these deposits are largely composed of materials which have been water-worn, in this feature reflecting the nature of the terrane from which the materials were eroded and on which they were deposited. The ice sheet on leaving the bed rocks of the mainland and the north shore of what is now Long Island sound passed over the Columbia gravels and sands, gathering debris from these older water-worn deposits; hence the water-worn pebbles which abound in the moraine even when the materials are truly ice-laid without stratification. True boulder clay occurs in small patches, but much of the till is sandy, and even in its coarser phases often exhibits traces of water action closely followed by a shoving of the deposits into contorted drift.

The outer deposits consist of a few low knobs rising like kames from the surrounding gravels. They bear a few boulders on their surface and frequently in road cuts reveal a thin patch of till. West of Searington rolling surfaces of till composed of a gravelly boulder clay give the deposit, along with its steep southerly front, something of the aspect of the main moraine as it exists southwest of Lake Surprise. These knobs and their rare attendant basins have a much less strong development than those heavier accumulations which lie in the form of a strong ridge immediately north of them. The deposits do not afford in themselves precise indexes of the position of the ice front at the time they were made. They appear to be submarginal deposits laid down when the ice front lay somewhat to the south of them, and are best compared with the kame moraine in the eastern part of Nantucket.

The inner or main moraine exhibits likewise the two phases of

building by the direct action of the ice and through the accumulation of gravels by water action.

The till phase of the moraine in this area is best shown in a road cut about one mile south of East Norwich. The till is here decidedly gravelly rather than clayey, with cobbles up to 20 inches in diameter, rarely, though occasionally ice scratched. The topography is cast into small knobs more distinct than the 20 foot contour lines of the map can be made to show. The hill over which the road in question passes has a drumlinoid curve, as if the ice had overridden it.

The overriding action of the ice shown in the boulders deposited on water-worn gravels in the moraine and by the ice swept curves of many of the knobs is further attested by the outlying meridional ridges between the inner and outer lines of moraines just north of Westbury pond. Their massiveness and accordance in elevation with the inner ridge are good evidence that they were formed by the same phase of ice action which was concerned in the construction of the main ridge of which they are but spurs.

The thick till phase of the moraine proper shades off imperceptibly into the thin till phase of the upper surface of the gravel plains on the north. This latter drift appears to be, over most of the area, ordinary ground moraine like that on the mainland far north of the moraines. Only here and there and particularly on the extreme eastern border of the Oyster Bay quadrangle do considerable patches of till with morainal topography lie north of the main wall, but none of these have the aspect of a frontal deposit. They are, rather, thickened deposits of the ground moraine, and their principal relief is molded on the ridges and valleys of the older drift which they mantle. They have therefore on the map been distinguished from the deposits which by their linear arrangement and massiness more clearly pertain to deposition at or immediately beneath the ice front.

The stratified gravels in the moraine appear to belong to two distinct categories as regards the mode of their origin: 1) outwashed gravels laid down at the ice front and subsequently pushed up into ridges; 2) high cones or fans deposited along the ice front by outpouring streams either from fountains such as Russell has described

on the Malaspina glacier; or 3) deposits made in water-eaten cavities in the ice front. As a rule, the gravels are seldom so well exposed as to reveal the structures on which a decision as to their precise character can be arrived at; and their origin in the presence of the ice in all cases being so intimate as to permit the falling of erratics on their surfaces makes it difficult to discriminate them from the gravelly till. This is particularly true where the growth of trees and the overturning of the superficial deposits have broken up the original stratification in the surficial portion so that the materials have the structural appearance of till or at least ice-deposited gravels. The deposition of the surface gravels by direct ice action is sometimes shown by the scratches on hard silicious pebbles. These scratches are usually miscroscopic and would have been quickly effaced by water action. Such pebbles occur in the churned up gravelly drift on the surface of the Columbia north of the moraine. The structure of the principal knob in this moraine chanced to be revealed in the summer of 1900, and the following notes on Harbor hill show the surprising development of these water-worn gravels in the deposit.

Harbor hill. The precise mode of accumulation of the materials in the terminal moraine still demands explanation in numerous details, particularly in regard to those portions which are mainly composed of stratified gravels and sands. Nowhere in the moraines on the islands off the southern shore of New England does this problem become more urgent for a satisfactory answer than in Harbor hill, a towering mass of stratified gravels, forming the culminating point of the moraine on this quadrangle at the eastern side of the pass through which the glacial drainage escaped from Roslyn bay to the great south plain. This hill rises with steep slopes into four knobs, the highest of which has an elevation of 391 feet, its base on the outwash plain being roughly circumscribed by the 200 foot contour line.

At its eastern base, the hill is separated from the extension of the morainal wall in that direction by a distinct depression, or trough, one of those numerous channels which gave exit to the intraglacial waters on to the outwash plain. On the west, its slopes fall off to sealevel at the head of Hempstead harbor. The high

point named is composed of stratified gravels and sands with yellowish layers, dipping nearly flat on the north side of the summit but inclining to 30° south, and evidently truncated on the west. This section was exposed in June 1900 in the excavation for a large house then in process of erection. Other small sections in driveways along the western slope exhibited stratified beds dipping in places 5° northward and usually eroded. On the western slope bouldery till, reddish from oxidation, appears about 5 feet thick; but till is wanting over the summit, which evidently has not been run over by the ice.

A complete section through this hill would be required to satisfy the needs of an exact analysis of its mode of formation; but the gravel beds dipping 30° south at the summit on the southern face of the knob appear clearly to place it in the group of glacial cones, formed along the ice front, homologous to the alluvial cones which form in the lower course of a drainage furrow on the side of a mountain valley, with this difference, that the mass at whose base it was formed, being ice, has melted away.

The glacial gravel in these cones and mounds arranged along the ice front, would appear to have been washed off from the top of the thinning ice border or to have issued from tunnels in the upper part of the ice. The character of the material in Harbor hill gives a decisive clue to its origin. The gravels are mostly yellow quartz from the older Pleistocene deposits which flank the moraine on the north. They probably have not been transported for distances greater than 10 miles; they may have been caught up from the base of the ice within 3 or 4 miles. At all events, they are locally derived material already existing in the district when this advance of the ice was accomplished.

The elevation of Harbor hill, nearly 400 feet above present sea-level, affords conclusive evidence as to the least estimate which may be made on the hight of the ice front at this point. This hight was at least 400 feet and probably more. This least elevation agrees well with the data found by Smock[1] in the longitudinal valleys of northern New Jersey, where ice tongues rose northward for a few

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[1] Smock, J. C. On the surface limit or thickness of the continental glacier in New Jersey and adjacent states. Am. jour. sci. 3d ser. 1882. 25 : 339–50.

miles at the rate of 30 feet to the mile. Such an elevation of the ice sheet increasing northward over the sound and on the mainland would give great hydrostatic pressure to the subglacial drainage, the effect of which would be to produce violent discharge at the front in any direction, outward or upward, in free coursing streams on the one hand and in fountains along the crevassed, drift-blocked ice margin on the other hand, in the manner of the discharge from the border of the Malaspina glacier as described by Russell.[1] An overladen stream, scouring the gravelly bed of the glacier and rising at the front through a shaft to a point of discharge on the margin, would drop that material at the margin in a high cone, whose ultimate form would depend on the degree to which it was deformed by irregular deposition on buried masses of ice, the melting of which would let down those huge kamelike heaps of gravel in the form of mounds along the ice front.

Distinction between outer and inner moraine. Two very distinct lines of moraines, designated as the inner and the outer, typically developed on Cape Cod on the one hand and on Nantucket and Marthas Vineyard on the other, have long been recognized by American geologists, and have been traced with much certainty across the intervening stretches of sea and land or islands to Long Island, most successfully by Warren Upham,[2] whose name and labors must ever be associated with the glacial deposits of this region. Mr Upham evidently regarded the inner of these two lines of moraines as terminating, so far as its relief above sealevel is concerned, at Port Jefferson. The morainal ridge which extends from the vicinity of Coldspring to New York narrows was regarded as the outer moraine. This interpretation has, so far as I know, ever since been generally accepted,[3] and the moraines have so been represented on compiled maps, leaving as an unsolved problem the question of what has become of so well defined a moraine as that which from Port Jefferson eastward has been known as the inner moraine,

[1] Russell, I. C. Second expedition to Mt St Elias. U. S. geol. sur. 13th an. rep't. 1893. pt 2, p. 81.

[2] Upham, Warren. Glacial history of the New England islands. Am. geol. 1899. 24 : 79–89.

[3] Chamberlin, T. C. U. S. geol. sur. 3d an. rep't. 1883. map, pl. 33.

a deposit which is almost everywhere in its extent more massive than the outer moraine.

The writer is led by his observations of the two moraines on Long Island to dissent from this long accepted opinion, and to regard the inner moraine as continuous westward of Port Jefferson to the vicinity of Coldspring and Syosset, where the two moraines nearly coalesce. They maintain their relative positions with some distinctness to the vicinity of Roslyn, where the inner moraine crosses the outer moraine, the latter disappearing beneath the later one, which continues onward to the western end of the island and becomes the terminal moraine of the mainland. The tracing of the two moraines made in the fall of 1900 by J. E. Woodman served to show the extension of the inner moraine to the southwest of Port Jefferson on to the eastern limits of the Oyster Bay quadrangle.

This interpretation of the westward extension of the two moraines is quite in line with the observed tendency of the ice front along the southern coast from the easternmost point in Massachusetts to the Hudson river. On the east the moraines of Nantucket and Cape Cod are at the outer margin of these two lobes more than 25 miles apart. In the region of Vineyard sound they are from 5 to 10 miles apart; they are quite 10 miles apart in the meridian of Block island; when they reappear on Long Island, they approach each other. West of Roslyn, the second moraine crosses the first. From this it is concluded that the inner moraine is not so much a recessional moraine as a frontal moraine built after a retreat from the position of the first moraine, followed by an advance to the position of the second moraine, accompanied in the Hudson valley by a greater outrun of the ice sheet than in the first advance. This overlapping of moraines is a well attested phenomenon in the region south of the great lakes.

The ice front which rested against the north coast of Long Island in the vicinity of Port Washington can not well be the same as that whose moraine caps the cliffs east of Port Jefferson. In the first place, at Port Washington the morainal accumulations are very slight indeed and do not rise in mounds; in the second place, the ice sheet halted there for a brief time only, as is witnessed by the small amount of outwash in the sand plain at that locality. This

halt is rather to be compared with those nearly stagnant ice fronts which are marked over southeastern Massachusetts and in the Narragansett bay region by similar sand plains formed in the retreat of the ice from the long maintained frontage on and against the Cape Cod moraine, a stage everywhere on these islands marked by well developed outwash plains.

Glacial streams. The course of glacial streams escaping from the ice front and extending over the frontal plain on the south side of the island is plainly indicated by the creases extending from the moraines near the head of the north shore harbors and from other passes in the main moraine. The principal of these streams seem to have followed the course of the harbors, if we may judge from the cross-section of the erosion channel or interruption of the moraine where they crossed it. The most instructive of these channels across the moraine is at Roslyn; there is another at Manhasset, and still another less marked at the southern end of Greatneck bay.

In each of these cases the larger valleys quite up to the pass in the moraine appear to have been occupied by ice at the time the ice sheet began to melt away. The *thalweg* north of the pass or divide rises steeply, usually from the bay side, invariably much steeper than the gradient of those valleys which, elsewhere on the surface of the plains north of the moraine, have been interpreted as older than the last ice advance. The pass in the moraine north of Creedmoor at the southern end of Little Neck bay is about 150 feet above sealevel; that of Manhasset bay is about 170 feet. The Roslyn channel is at about 130 feet. There is thus no accordance of level in these outlets.

Other passes across the main or inner moraine occur west of Roslyn at about 230 feet, and east of Harbor hill at about 90 feet. Southeast of Brookville there is a pass at about 230 feet, and south of East Norwich another at about 210 feet. All of these appear to be more or less in line with certain valleys north of the moraine, and all of them lead out south of the moraine into creases which descend to the sea.

The broad depression passing by Locust Grove toward East Norwich is not wholly erosional in origin. Just north of the road at Locust Grove the bottom descends into a large elliptic pit suggesting

the one time presence of an ice remnant. The margins of the depression also are contoured as if by deposition against a mass of ice. It is precisely in this portion of the ice front that the crest of the moraine bears indications of having been overridden by the ice (p. 638).

The transmorainal water courses are best studied at Roslyn. At this point the glacial stream excavated a trench nearly 40 feet deep in the gravels immediately adjacent to the moraine on the south, forming well defined terraces fairly well brought out by the contours on the map. About a mile below Roslyn this crease turns sharply eastward for half a mile, then straightens out and continues southward by Albertson, to the east of East Williston and thence to the sea.

The frontal plain near Creedmoor exhibits no marked trace of a crease, and many creases which are distinct on the outer southern margin of the outwash plain become faint and practically disappear as surface features nearer the moraine. This fading of creases would be caused by the wandering of streams over the surface, spreading gravel and sand, with the aggradation or building up of the plain by the streams near the ice front so long as they were overloaded with debris.

The creases on the eastern part of the Hempstead quadrangle are deflected southwestward into the Jamaica bay depression. East of that region, the streams flow generally southward, the numerous creases marked by the 100 foot contour line, for instance, gathering southward into six or seven drainage channels through which small streams now drain the water from the plain.

Outwash plain. The outwash plain is evidently more complex in its origin that its mere surface would indicate. The disappearance of the older Pleistocene gravels beneath the moraine on the north at about 200 feet above the sea has already been noted. Just as the level of these deposits falls off on the north side of the moraine to the westward, so does the hight of the outwash plain, and, for that matter, that of the main moraine itself. There is good reason for holding therefore that the so-called Columbia deposits extend south of the moraine and presumably underlie the outwash plain, if they do not actually form here and there surface exposures.

Yellow and yellowish gravels occur in some of the railway cuts, but it has not been possible in the present survey satisfactorily to delimit such older deposits, except in one case, that of the Far Rockaway ridge. This peculiar deposit is described on p. 651.

The materials exhibit at surface a gradual diminution in coarseness from coarse gravel near the inner moraine to fine sands at the outer limits of the plain. A shallow excavation in the county building site at Mineola exhibited alternating layers of coarse, nut-sized gravel and fine sandy gravel with feebly developed crossbeds at intervals. The pebbles were mostly white quartz and gneiss, this latter often decayed. More rarely were seen small pebbles of ironstone and a ferruginous conglomerate of white quartz pebbles. Pebbles as large as 3 inches in diameter were extremely rare.

A rather anomalous element for the upper part of the section of the plain is the brick clay found at East Williston. While clays would normally develop about the margin of a plain of this character in the sea, to be subsequently overlain by the outward growth of the thickening plain, such clays would hardly be formed with a surface so nearly that of the completed gravel plain; and it is probable that these are either an older degraded deposit or owe their position to the deformation and uplift of the basement on which the deposits and topography of the last extraglacial streams have been imposed. The section, which is exposed in a somewhat depressed, troughlike area, is as follows:

SECTION OF CLAYS AT EAST WILLISTON

	Feet
Soils	1.5
Sand, gravelly, with quartz and granitic pebbles, locally reddened	8
Clays, sandy, with quartz pebbles	
Clay, sandy in yellow band	
Clay, blue, finely laminate, rarely with quartz pebbles, exposed	3

The section is apparently conformable throughout. Crosby, if I understand him rightly, would refer these clays to the Tertiary.

The manner in which the water percolating through the sand plain north of and above the 60 foot contour in the Hempstead

quadrangle comes to the surface south of that limit and flows in small streams to the sea suggests that clays are there immediately beneath the surface veneer of sand and fine gravel.

The surface slopes seaward at the rate of about 15 feet to the mile. Aside from the drainage creases above referred to, no other lines of water action have been found within the area. The line of contact with the moraines gradually rises from west to east, very much as the elevation of the older Pleistocene increases on the north of the moraine. Everywhere the plain appears to rise continuously to the base of the moraines. The only possible exception to this statement is found in the barlike ridge which lies northeast of Hicksville; but the northern slope of this bar, much steeper on the whole than its southeastern face, is not conclusively to be compared with the northern margin of a frontal terrace plain such as that of Nantucket, in which the outwash of sand and gravel has carried the deposit up against the base of the ice front. If this deposit were of such an origin, its northern slope would fix the front of the ice at the time of the making of the outer line of morainal deposits, about half a mile in front of the submarginal moraine, and this gravel bar would somewhat antedate the part of the creased plain lying to the west.

The plain everywhere on the south sinks beneath the surface of the marsh without trace of a shore line action. So far as its present surface is concerned, it appears to have arisen by the outwash of streams in the manner of those extensive sheets of gravel, sand, and glacier mud which confront the Malaspina and other existing glaciers in high latitudes at the present day.

With the completion of the inner moraine and the sheeting over of the southern outer slope with gravels and sands creased by outrunning streams, the principal work of the ice sheet on this portion of the island ceased, and we next find indications of its front farther north along the blufflike descent to the present Long Island sound. This front is best marked at Port Washington and on the area to the westward shown on the Harlem and Brooklyn quadrangles.

Port Washington stage. The first definite trace of a halt in the ice front after the retreat from the main moraine is found on the northern and western extremity of Manhasset neck near Port

Plate 7

H. Ries, photo.

Section of glacial delta in Reed and Murray's sand pit, Port Washington. View from bluff above, showing fore-set beds dipping toward the south, the thin top-set beds, and the level surface of the delta at about 80 feet above present sealevel

Washington; hence the ice-laid and the water-laid drift of this episode are here assembled under the name of the Port Washington stage of ice retreat.

Whether some of the deposits lying south of this line and yet north of the moraine, as in the plain north of Greenvale station, may not constitute an intermediate series of deposits can only be determined by more evidence than the topography of the deposits alone affords.

From the village of Port Washington northwestward there overlooks the harbor a thick plain of sand with a lobate margin. These lobes point inward from the east and the north and have their summit line traced by the 80 foot contour line. The plain of sand is free from boulders, and its structure, as shown in numerous deep sand pits, consists of beds dipping everywhere southward toward the shore at angles of about 20°. All about the iceward edge of the sand plain are boulder-strewn fields, which on the north and west have a decidedly morainic topography below the 100 foot contour line. From near Plum point around the coast of the sound to Mott point this topography is very distinct, forming a rough slope to the sea rather than a ridge; but the morainal deposits, as shown at Barker point, are a mere veneer over older glacial beds.

The topography thus defined marks the overlap of the ice sheet at this stage on Manhasset neck, and the sand plain is a delta formed in a body of water whose surface was approximately at the level of the summit line of the lobate margin of the deposit.

It follows from this conclusion that, if other sand plains at this level occur to the east and west on the north side of the moraine within approximately the same distance of retreat from the main moraine, the probable position of the ice front at this later stage may be traced by drawing a line along the northern margin of these deltas.

Another such deposit less clearly developed occurs at Great Neck village at approximately the same hight; and, as the line between the inner margin of the sand plain and the ice edge on the western part of Manhasset neck turns in this direction, it appears legitimate to associate the two deposits in the manner indicated. The line thus drawn suffices to show that the front of the ice sheet was at

this time very irregular in outline as compared with the crest of the inner moraine (*see* pl. 9).[1]

As the land, on the south of the Port Washington stage, on the Oyster Bay quadrangle everywhere in the moraine rises to levels higher than 80 feet above the present sealevel but is open to the west, the nature of the body of water in which the deltas at this stage were built — whether fresh water or sea water — must be determined by observations drawn from outside the district. With this point in mind, the following notes from the Harlem and Brooklyn sheets throw light on the glacial history of this area.

Harlem and Brooklyn quadrangles

For the purpose of comparison and in order to follow out to some definite conclusion the problems arising on the area heretofore dealt with, a reconnaissance was made of the region on the west. The questions which have thus far arisen are the distinction between the inner and the outer moraine, the nature of the water body in which the Port Washington delta was deposited, and incidentally the reason for the diversion of glacial drainage on the outwash plain into Jamaica bay.

It has been shown how the "inner" moraine becomes the principal and outer moraine west of Roslyn. From this vicinity, particularly near Hollis, to the western limit of the island the alinement of the front of the moraine at its merging into the sand plain is strikingly uniform in direction. From 2 to 3 miles east and west of Jamaica this line certainly is suggestive of an ancient shore line, now at about 80 feet above the sealevel.

A number of newly cut streets expose the glacial deposits along this line, particularly on the crest and frontal slope of the moraine in the vicinity of Jamaica. The moraine near the front is composed of till with medium-sized boulders, often passing into an ill stratified, contorted drift, with lenses of till and gravel, the topography of the whole being of the knob and basin type.

The frontal slope of the moraine inclines from 15° to 20°, an

[1] On the colored geological map accompanying this report, the deposit at Great Neck village is not discriminated from the older Manhasset sands for the reason that no section of the deposit was obtainable.

LEGEND

RECENT
AND NOW FORMING

Rml — Marine alluvium beaches of gravel and sand

Eod — Eolian deposits, dunes and blown sands

PLEISTOCENE

WISCONSIN EPOCH OR LAST GLACIAL

Pwm — Glacial sand-plains, Port Washington stage, Sand and gravel

Pwm — Morainal deposits of Port Washington stage over older glacial deposits

T — Veneer of till and erratic blocks north of the inner moraine

Hhm — Moraine of the Harborhill stage gravels at Harborhill typical till in other places

Km — Kame moraine areas with scattered boulders, marking outer moraine

Op — The outwash plain of gravel and sand

OLDER PLEISTOCENE

Mg — Manhasset gravels and sands under T

Mbb — The Manhasset boulder bed, a local glacial deposit in the Manhasset sands

PRE-PLEISTOCENE

Fyg — Far Rockaway gravels yellow gravels

Cr — Cretaceous clays and sands in disturbed positions

X Gravel and Sand pits

Clay pits

Kodak "pits

Topography by U. S. Geological Survey in cooperation with the N. Y. State Engineer and Surveyor

Scale 1/62500

Contour interval 20 feet.
Datum is mean sea level.

Pleistocene Geology by J. B. Woodworth
Surveyed in 1900

J.B. & LYON, STATE PRINTER

angle rarely as steep as that of repose of sliding materials on an ancient cliff whose base has been abandoned by the sea. One such steep place a few yards in length occurs between Jamaica and Hollis.

Along the base of the slope at the inner edge of the plain, if wave action had determined the lineality of the morainal front and secondarily its slope, there is a lack of the critical evidence which one would expect to find at the place. The generally unstratified character of the deposit forming the morainal front offers little evidence as to whether it has been cut back by wave action or not, but on the west side of Prospect park in Brooklyn decisive evidence on this point is found.

West of Prospect park the morainal front maintains its lineal course toward New York narrows, but with a rather bulging frontal slope composed of stratified gravels. As seen in pits open in the season of 1900, these stratified gravels rise up steeply from the northern margin of the frontal plain, then bend downward into a large kettle-hole in the deposit, a depression marking the site of a mass of ice. The attitude of the beds suggests frontal shoving on the part of the ice sheet as well as irregular deposition; but the significant feature at this locality is the apparent absence of anything like a cut bench or cliff in the bulging front of the deposit.

The structure of the sand plain is exposed in occasional pits. The beds are prevailingly cross-bedded, showing frequent reversals in direction of the transportation of the sediments. Such cross-bedded layers occur in glacial gravels where there is no reason for supposing the sea to have acted on them.

On the east, on the Oyster Bay sheet, the inner margin of this frontal plain rises above the 100 foot contour level; in this region it sinks gradually below it, till north of the Jamaica bay depression, where the plain has a width not exceeding 1½ miles above sealevel, its hight next the moraine is only 60 feet; westward it rises slightly again. For a portion of its length, therefore, this line accords in elevation with the 80 foot level of the water body in which the Port Washington delta was built. If throughout the line accorded with the Port Washington level, it would favor the existence at that stage of a body of water in front of as well as in the rear of

the moraine. So far as can be seen, such a body of water must have been the sea, and it would be warrantable to suppose that the land stood 80 feet lower than now with reference to the ocean.

Jamaica bay depression

The possibility of such deformation of the frontal plain since glacial times as would produce the present departure from the 80 foot level along the northern margin is negatived by the peculiar depression known as Jamaica bay, whose origin it is now necessary to consider before arriving at a conclusion concerning the submergence or non-submergence of the island at the time of the Port Washington stage of ice retreat.

The semicircular area of marshes and salt creeks forming Jamaica bay outlines a remarkable depression in the outwash plain. The moraine immediately back of it is quite as well developed as for some distance east and west of it, nor is the crest of the moraine perceptibly lower at this point, where there appears to be a lack of development of the plain. The moraine shows therefore no signs of having been depressed at this point, and was formed probably later than the depression referred to.

That this depression in the plain is a feature dating from early glacial times and an original feature in the growth of the plain is also shown by the behavior of the creases or drainage channels which lead into the bay: these creases converge on all sides toward the depression, showing that the slopes of the plain were then as now toward this relatively unfilled area. It follows therefore that the plain has not necessarily been deformed since glacial times, and that the rising and falling of the inner line of contact of the plain with the moraine is an original constructional characteristic of the deposits. If this reasoning be correct, then the local coincidence in level of the inner margin of the plain with the level of the Port Washington delta is not due to the control of a water level common to both areas.

Moreover there is reason to believe that the frontal plain was mainly developed when the ice lay along the inner moraine previous to the Port Washington stage, and, as will shortly be stated, that the Port Washington delta was deposited later in a temporary lake confined between the moraine and the retreating ice front.

Concerning the origin of the Jamaica bay depression, it is intimately associated with another feature, the Far Rockaway ridge already mentioned as extending northeastward on the southeast side of the bay till it disappears beneath the sands of the frontal plain near Lynbrook. The structure of this ridge is not well revealed. So far as the superficial deposits go, they appear everywhere to be yellowish quartz gravels up to 3 inches in diameter. Like the depressed area northwest of it, the ridge appears certainly to be older than the surface features of the plain in its vicinity.

Barnum's island, lying to the east of the Far Rockaway ridge, was not visited; but the following well section, reported by Dr F. J. H. Merrill several years ago, would seem to indicate that the Far Rockaway gravel extends in that direction. The normal sediments of the outwash plain would be, at least at surface, at this distance from the moraine fine sand rather than gravel.

WELL SECTION ON BARNUM'S ISLAND[1]

	Feet
Sand and gravel, stratified	70
Clay and clayey sand with lignite	56
Gravel and fine sand with clayey sand	44
Blue clay, clayey sand and silt, with lignite and pyrites	168

Crosby agrees in referring the upper 70 feet to the yellow gravel.

The elevation of the ridge is quite uniformly a little more than 20 feet above the sealevel; its direction is parallel with the moraine on the north of it. This association of a depression which appears to have been in the process of filling by streams pouring from the ice front, with a bar of gravels older than the outwash plain, as their composition and form show, suggests the deformation of the Columbia or some underlying coastal plain formation at some time anterior to the completion of the moraine and its frontal plain. Such deformation might well arise as the effect of the imposition of the weight of the ice sheet on the yielding sediments previously deposited. In this view, the Far Rockaway ridge is an outlying, upraised fold, or "parma,"[2] and the bay a correlated depressed area,

[1] Merrill, F. J. H. Geology of Long Island. N. Y. acad. sci. Annals. 1886. 3 : 350.

[2] Suess, Edouard. La face de la terre. Paris. 1897. 1 : 820.

both of which are an effect of the early invasion of this part of the island by the ice.

On the other hand, it is possible that this bar may be the inner margin of a stratum of these yellow gravels, the low ground north of it being the unfilled portion of a longitudinal valley but it does not seem possible at present to demonstrate this view.

Glaciated ledges

Frontal moraines mark the position of the ice front. The motion of the ice, at least near its margin, will tend to be toward that front; hence, since the moraine in this part of the island trends to the south of west, forming a lobate line across this region and that adjacent in New Jersey, glacial striae in this part of the island should run to the east of south. A number of ledges of gneiss in Long Island City meet this requirement. One of the largest exposures of bed rock occupies a vacant lot adjoining the Queens county courthouse on the west. The ledge is heavily glaciated, forming a long, low *roche moutonnée*. The striae range in direction from 29° to 30° west (magnetic). A few striae run from n 15 w, and one set of scratches lies in a northwest direction. The strike of the foliation of the gneiss is n 25 e magnetic. Other outcrops occur to the northeast with striae running from the north northwest. A series of shallow oval depressions extends in a northwest and southeast direction across one outcrop, the whole bearing evidence of water action, presumably that of a subglacial stream.

The southeastward movement of the ice on this side of the Hudson valley is further attested by the drift. The moraine from Brooklyn as far east as Oyster Bay contains trap boulders, the nearest known site of which rock is in the Palisade trap ridge on the west bank of the Hudson river.

Stratified red sands, also undoubtedly derived from the area of Triassic red sandstones now found only on the west bank of the Hudson, occur in a section by the roadside from Corona to Astoria, being there overlain by 8 or 9 feet of gray till with trap boulders.[1]

[1] Boulders of trap and red sandstone were seen by Sir Charles Lyell in an excavation made in a boulder bed at the Brooklyn navy yard. *See* Lyell, Charles. Travels in North America. N. Y. 1845. 1:189–90.

This fanning of the ice sheet to the eastward on the east side of the lower Hudson and to the westward on the west side is consistent with the form of the moraine across the mouth of the river. The axis of the lobe thus indicated has been fixed by Salisbury on the west side of the Palisade trap ridge.[1]

From what has been stated, it would appear that the western end of Long Island is occupied by a moraine and a contemporaneous outwash plain built along the margin of the ice sheet, when it had, in this region adjacent to the mouth of the Hudson, pushed a lobate mass somewhat farther south than the limit attained by an earlier stand of the ice front, marked eastward by the outer moraine from near Roslyn to Nantucket; that the frontal plain in this district rises to slightly different levels against the front of the moraine, a feature which is constructional and not due to post-glacial warping; and that the front of the moraine as a whole presents no decisive evidence of having been subjected to marine action above the present level of the sea.

With this statement of the observations bearing on the marine limit at the time of the last ice invasion, it is necessary to return to the later ice phenomena exhibited in connection with the Port Washington stage of the retreat.

Port Washington glacial lake

It has already been pointed out that the last evidence of the presence of the ice sheet on the area covered by the Oyster bay quadrangle is found in a well defined delta and attendant ice-laid deposits occupying the semicircular tip of Mannasset neck. The phenomena indicating a halt of the ice front against this headland for a brief time subsequent to the retreat from the inner moraine at Roslyn are very clear. The conclusion having been reached that the area has not been submerged to the depth of 80 feet since the beginning of the deposition of moraines in this part of the island, it seems necessary to further examine the region to determine the possibility of this delta having been built in a temporary glacial lake.

To the north and west of Port Washington occur a number of gravel and sand pits opened in a characteristic glacial delta, whose

[1] Salisbury, R. D. N. J. geol. sur. An. rep't state geol. for 1893. 1894. p. 161.

upper surface, as indicated by the topographic map, is about 80 feet above the present sealevel. The outer, or southern edge of this delta is sharply lobate, each lobe corresponding, as in existing deltas, to the end of some distributary stream coursing in glacial times over its surface to the body of water in which the deposit was accumulating. Taking the summit line of these lobes as indicating the water level of the time, it is evident that the water body rose 80 feet above the present sealevel. We shall examine presently into the question whether this water was the sea or a lake held in on the north side of the moraine by the ice sheet which still occupied Long Island sound.

The front of this sand plain or delta is concave toward Manhasset bay, trending northward from Port Washington and then westward about one mile beyond the village. This form of the front is accordant with the outline of the outer curve of the neck. At a distance varying from half a mile to a mile from the lobes the glacial stratified sands pass into till, and the level surface of the old delta gives place to a hummocky topography, sloping generally toward the open waters of the sound, plainly indicating the deposits which were laid down in the presence of the ice or beneath it while the waters pouring from the ice constructed the delta. We thus have the picture of a small semicircular embayment of the ice front. From an inspection of the ground, it appears that the edge of the ice lapped over on the existing land for a distance of three fourths of a mile to nearly a mile from Barker point, around by Sands Light point, and for a slightly greater breadth on the eastern side, at least as far as Mott point. Beyond this locality it is quite impossible to discriminate the deposits of the ice made at this stage from the earlier deposits laid down when the ice front was closely pressed against the moraine on the south.

The structure of the delta as exposed in the summer of 1900 is typically deltiform, with beds of sand steeply inclined toward the frontal lobes, each bed having been deposited in its present inclination on the growing edge of the delta, as the streams coursing over the embankment, already built up to water level by this process, came to the outer margin and let their load of sand come to rest by sliding down the frontal slope to the angle of repose for that material in water. (*See* pl. 7 and 8)

Plate 8

H. Ries. photo.

Section of glacial delta in eastern sand pit, Port Washington, showing fore-set and overlying top-set beds. View looking north

In the southern part of the sand plain exposed by excavation, the inclined, or fore set beds are not overlain by any distinct coating of horizontal, or top set beds but farther north such layers appear. (*See* pl. 8)

The bit of evidence here presented concerning the form of the ice front shows that the margin at this time was less regular than when it lay against or on the high moraine from 4 to 5 miles south. It evidently extended across Manhasset bay from the vicinity of Plum point to the opposite shore and thence westward lay against the land at least as far as College Point, where again there was built a small delta deposit later than the moraine. There is good reason, therefore, to believe that the water body in which the delta at Port Washington was built was cut off from the sound along the north shore of the island, and that the sound was as yet filled with glacial ice. Just north of Port Washington village, there is a deep channel or furrow beginning in the trough occupied by the middle one of three ponds and extending northeastward across the gravelly and till deposit to the vicinity of Mott point. The bottom of this trough, whose contours are shown on the topographic map, is about 75 feet above the present sealevel. The trough has the form of one of those creases eroded or kept open by water flowing out of the ice sheet or from one glacial lake to another along the ice front. At the time it may have connected the waters confined in Hempstead bay with the water held by the ice sheet in the Manhasset bay depression.

The crease at the southern end of Hempstead bay, at Roslyn, shows clearly that a stream once discharged there across the moraine on the plain, with its bed over 120 feet above the present sealevel. Hempstead harbor is bounded on the east quite up to the sound by land rising above 100 feet, so that, when the ice front retreated from the morainal wall at Roslyn, drainage would continue to escape through the Roslyn channel till the Mott point channel was opened by the retreat of the ice north of that point. At this stage any open water in Hempstead harbor would have escaped into the Port Washington body and its level fallen off to about 80 feet. This arrangement of cols and drainage channels, considered in relation to the retreat of the ice front, proved by the Port Washington stage,

makes it highly probable that for a time Hempstead harbor was the site of a small glacial lake, at first discharging at the 120 foot level at Roslyn, and later by the 80 foot channel into the Manhasset water body. It now remains to determine whether the high level of water in Manhasset bay was then at sealevel or whether it too was held up by a glacial barrier.

South of Manhasset is a col in the moraine, at an elevation of about 175 feet, much higher than many cols separating the bay from lower passes through the moraine in the country on the east of the bay. It is evident that this col, which lies just east of Lake Surprise, could not have been used as an outlet for the water confined in Manhasset bay after the ice front had retired as far north as Port Washington, for the water level had then fallen to 80 feet, as witnessed by the delta at that locality.

West of Manhasset bay, most of the region north of the moraine fails to attain the 100 foot level. The moraine itself presents a continuous barrier rising above the 80 foot contour line at all points till the vicinity of Maple Grove is reached. Between this locality and Prospect park in Brooklyn, there are eight or nine low, troughlike passes across the crest of the moraine, which might have served for the overflow of water held in on the north between the moraine and the retreating ice front as late as the Port Washington stage, while the ice, on account of its greater activity near the axis of the Hudson lobe, maintained its position close to the moraine in the vicinity of Brooklyn, at least depassing the 80 foot contour line on the back of the moraine so as effectually to prevent discharge by a lower level into New York bay north of the Narrows.

These troughs across the moraine are singularly uniform in level. In all those enumerated their bottoms lie according to the government survey between the 100 foot and the 80 foot contour lines. Some of them are clearly inosculating kettle-holes, marking the site of melting masses of the ice. From some of them, drainage creases can be traced out over the frontal plain. They are best developed in line with the bays and depressions on the north side of the moraine, and hence were probably the paths of subglacial streams, as in the case of the passes on the Oyster Bay quadrangle. They are however not unique in this portion of the moraine. There are

other similar passes at higher levels. Their coincidence of level is apparently accidental; but their repetition not only determined the level to which delta construction should reach in the temporary lake behind the moraine at this stage, but the fact also explains the failure to depart from that approximate level while the ice maintained its position. With the possibility of the water spilling over through several or all of these channels, the drainage, if the time were short, would hardly concentrate on any one of them. That the time was short, is shown by the small delta built at this level. Where the outpouring stream from the ice was strongest, the delta pushed out about a mile.

The deep drainage furrow dissecting the delta on a north and south line indicates a sudden falling off in the water level. This undoubtedly points to a change in the position or in the solidity of the ice barrier on the west, such as to permit the confined waters to escape into New York bay at a lower level than the passes in the moraine. The fact of such a change of level is indicated in a small delta at about 40 feet in the vicinity of College Point.

College Point delta

A poorly developed delta fringes the southern slope of the bar of glacial drift which connects College Point with the village of Whitestone. The northern slope and much of the crest of this ridge are morainal, though sands are exposed here and there beneath this ice-laid coating. At a point about due south of the bottom of Powell cove, a section open in June 1900 showed the fore set and top set beds of a typical delta structure extending southward. The structure as in fig. 9 indicates a period of building at about 35 feet above the present sealevel, followed by a rise of the water level of about 5 feet, the whole indicating clearly a water body north of the main moraine at about 40 feet above the present sealevel.

The ice front had now evidently retreated along a part of the line somewhat north of its position at the Port Washington stage. That this retreat was not without slight advances, is probably indicated by the evidence of rising water level in the College Point delta; but the opening of crevasses in the ice margin and their sub-

sequent closing might under the local circumstances have accomplished, as in existing glaciers, such minor changes of water level.[1]

A glance at the topographic map will show that from Flushing bay, the shore line of which at the time the College Point delta was deposited must have been about 40 feet higher than now, there is a well defined channel extending westward from Newton through Winfield Junction to the head of Newtown creek. From this point escape of the water to or connection with the sea was possible either along the northwestward course of Newtown creek to the East river at Hunters point or, if that way was still blocked by the ice sheet, along a more southerly course between Williamsburg and Brooklyn into Wallabout bay, the highest land there lying between the 20 foot and 40 foot contours. From Wallabout bay a somewhat winding passage below the 40 foot level was open, permitting discharge into or connection with Gowanus bay just north of the moraine at the Narrows.

Fig. 9 Cross-section of the structures observed in the College Point delta. *a*, fore-set beds; *b*, top set beds; *c*, morainal ridge or bar

As for the possibility of the 40 foot delta at College Point having been deposited at sea-level, it should be stated that similar formations north of the moraine indicate widespread waters at about this level. When these have been fully investigated it may be necessary to admit a submergence to this extent. What is stated here must be taken with this reservation in mind.

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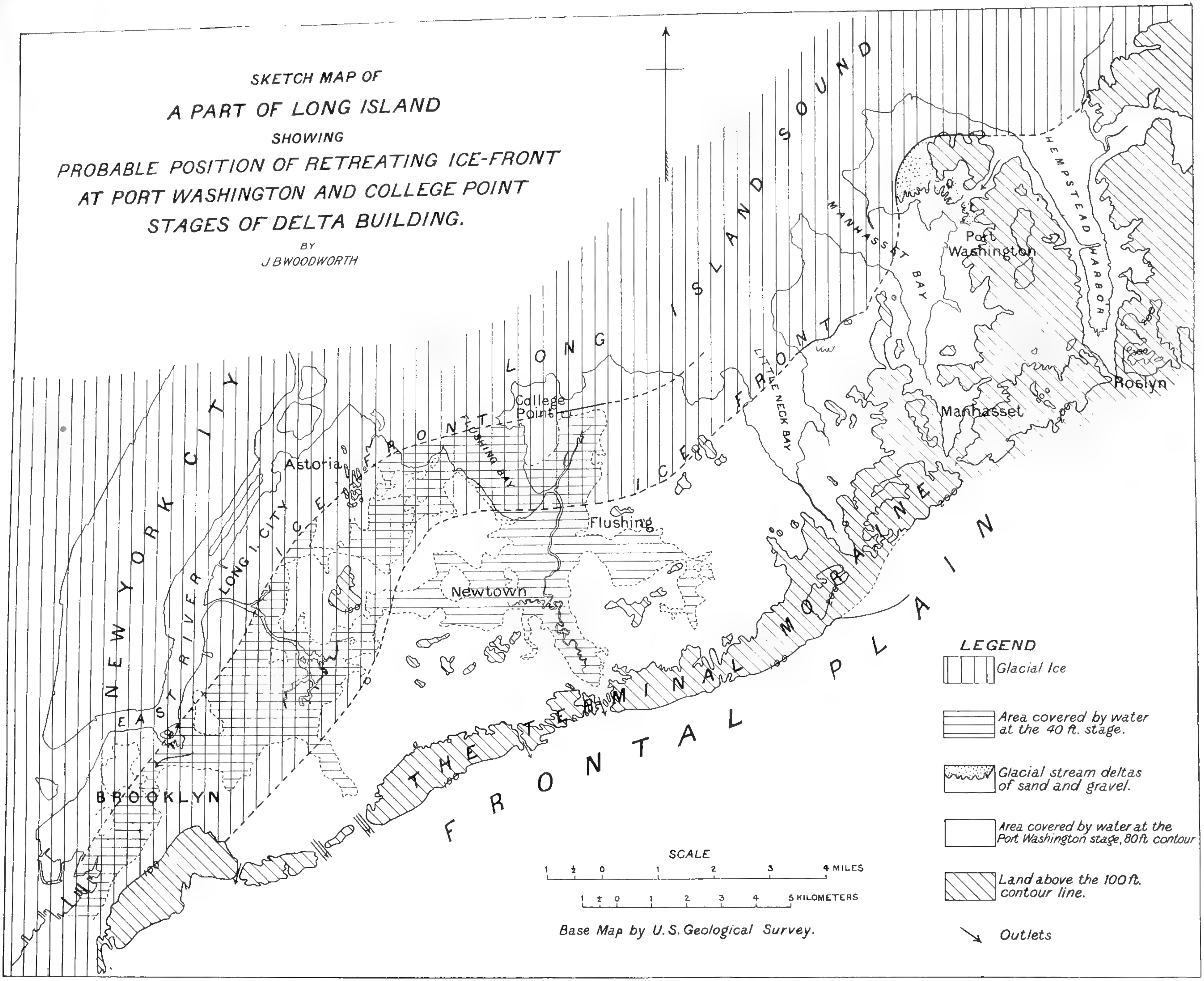
[1] See, on the formation of temporary lakes at the present time, Edouard Suess, La face de la terre. Paris, 1900. 2 : 590–97, and the authors there cited; also De Lapparent, Traité de géologie. 4me ed. Paris, 1900. p. 302–3, on the sudden drainage of glacial lakes. For American glacial lakes of the class here described, see H. B. Kümmell, Lake Passaic, an extinct glacial lake, in N. J. geol. sur. an. rep't for 1893. Trenton 1894. p. 225–328; separately printed 1895. p. 1–89; Crosby and Grabau, Glacial lake deposits near Boston, Science. 1896. 3 : 212–13; also Grabau in Crosby's Geology of the Boston basin. 1900. v. 1, pt 3, p. 564–600, pl. 25; and Warren Upham, The glacial lake Agassiz, U. S. geol. sur. Monograph 25. 1895. 658 p.

The position of the ice front is definitely fixed in this field during the retreat by certain sandy deltas backed by morainal deposits. Elsewhere in the retreat from the main moraine, the position of the ice front is indefinite. In the hypothesis of glacial lakes held in by it, it is placed at certain points so as to control the outlet of water bodies or lakes whose level is known. There are in this district certain drift ridges which simulate the form and extension of the main moraine, and they appear to have developed in part during the retreat from the outer ridge at East New York. Their trend and position accord as nearly as might be expected with the position of the ice front at the time of the Port Washington and College Point stages.

In a broad sense most of the western part of the island north of the moraine is morainal. But it has a distinct aggregation in belts rudely parallel to the outer moraine and presumably to the ice front as it retreated. Some of the thicker deposits may be due to the working over of the moraine whose disappearance beneath this later drift at Roslyn has been noted.

A glance at the contours on the map will show a line of irregular, flattish drift hills with hollows lying about 2 miles north of the main moraine. This line is encountered at East Williamsburg. On the north and west of Corona is a curved line of deposits highly suggestive of an ice margin, and the phenomena are repeated in deposits bending around from East Calvary cemetery near Hunters northeastward past Ravenswood into Astoria and thence to the East river near Sanford point. This line is, again, about 2 miles farther back than the Corona line, and the two bend southwestward toward New York bay, as the line might be expected to bend if the ice were not completely stagnant along the axis of most rapid movement down the Hudson valley. Moreover, the Astoria line is apparently a continuation of the College Point frontal deposits, and they are so represented by the line drawn on the accompanying sketch map (pl. 9). The line of the Port Washington stage is not so definitely known. From Littleneck bay it is represented as following the Corona deposits; it may have rested against the drift hills on either side of the southern end of Flushing bay; the results are practically the same in either view.



The map includes the area from Roslyn and Glen Cove on the east to Brooklyn and from the moraine to the north shore. The obliquely ruled black lined areas comprise land above the 100 foot line. The unruled area between the moraine and the heavy black line representing the Port Washington ice front gives the approximate extent of the fresh-water lake held in at the Port Washington stage. The dotted surface with lobate margins shows the position of the delta of that stage, and the arrow indicates the channel through which the Hempstead bay lake drained into Manhasset bay lake, from which in turn the water may have escaped into the Little Neck and Flushing bay region, and so spilled over the moraine in some one or more of the low passes marked by small arrows.

SUMMARY OF GLACIAL HISTORY

From what has been stated of this district, it appears that relatively early in the Glacial period the area now forming the western part of Long Island received a thick coating of gravels and sands, some of the debris being eroded from the deposits of the coast plain remaining in the area, some of them being borne from the mainland on the north; that probably somewhere near the middle of this time, as indicated by the occurrence of the deposits in the section, there was an actual invasion of the district by ice, either floating ice or land ice, in either case probably the margin or detached floating portions of the front of an ice sheet laying down till in the district. These deposits as a whole underlie the moraines and are apparently the Columbia formation of McGee. Certain aspects of the deposits seem to be paralleled in New Jersey by the yellow gravel formations described by Salisbury.[1] Subsequent to their deposition, which locally affords no decisive evidence of the relation of land to sealevel, they appear to have been somewhat dissected by open air streams, indicating an epoch of deglaciation or ice retreat of indefinite duration. Following this came the deposition of two lines of moraines in the area, an outer and inner or earlier and later, but in the western part of the field the later ice front depassed the position of the earlier advance. The land appears to have been as high above sealevel as it is now, if not higher; and during the retreat of the ice one or more temporary lakes existed back of the moraine, first at 80 feet above the present sealevel, then possibly at about 40 feet. This lower body of water may have been at sealevel as stated above. With the retreat of the ice front across East river, the region escaped from the field of glacial action, and its latest glacial deposits and features pertain to the very beginnings of the ice retreat, a time but slightly past the culminating phase of the last or Wisconsin glacial epoch. Of any such distinctions as a Champlain and Terrace epoch there appears here no trace, for the overwash plain was making while the ice was at its maximum extension, and the glacial terraces marked by the small deltas described in this

[1] Salisbury, R. D. N. J. geol. sur. An. rep't state geol. 1895. p. 67–72.

report were made before the ice had melted back 5 miles from its extreme prolongation. They clearly belong however to the period of retreat; but the mainland on the north was still actively glaciated.

POST-GLACIAL CHANGES AND PROCESSES NOW IN ACTION

The disappearance of the ice from a glaciated district of itself induces certain changes which are not wanting in this part of Long Island. The melting out of remnants of the glacier or those parts of its base which filled depressions has in many instances given rise to small lakes and tarns. A number of these small lakes exist in the moraine west of Roslyn. Of these, Lake Surprise is the best and largest example. It lies at an elevation of about 200 feet above the sea in a basin whose sides are gravelly till. Presumably the bottom is clay rather than gravel, as the waters would escape through the latter. Such lakelets depend on the percolation of the ground waters through the relatively gravelly or sandy materials of the superficial deposits, the water standing in the pond at the level of the ground water in the gravels. Other small lakelets lie in depressions in the outwash plain, as at Plattsdale. Westbury pond is one of this class named on the map.

The streams of the plain flow, as has been indicated, in courses which were carved out by the once more vigorous glacial streams or in still older channels on the north side of the moraine. Owing to the porosity of the glacial gravels, much of the rainfall soaks into the ground and issues near sealevel in the form of springs, hence, since the run-off is small, little erosive work has been accomplished in the post-glacial epoch. Yet the streams which converge into Oyster bay have contributed enough gravel and sand to form a narrow flat, modified by wave action where the village of that name stands.[1]

Marine action at the present sealevel has cut back the outwash plain on the south coast as well as the Far Rockaway ridge, so that the outermost extent of both of these formations is now destroyed,

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[1] In June 1900 a well bored by means of a drill on the north side of Main st. 760 feet distant from the beach met at the depth of 45 feet (35 feet below sealevel) a marl containing oyster shells (*Ostrea* sp). Above this bed were gravels, below light yellowish sand.

and a low bluff faces the sea. Bars of sand have been partially or wholly thrown across the old glacial stream channels by the waves. The most notable of these marine deposits are in the form of offshore bars, subject to frequent changes in hight and position.[1]

On the north shore, where the wave action is less vigorous, there has been less cutting back, but, the cliffs being higher, other factors, such as landslips and the ordinary work of gravity on loose materials, nearly compensate for this difference in the quantity of materials handled by the waves. The wave action on this side of the island has been in part resisted by the numerous boulders which come to rest upon the beaches from the undercutting of the till, a feature which is wanting on the south shore. Numerous small barrier beaches occur, usually with outlets at their western end for the lagoons or back bays which they inclose. A few small masses of land, which otherwise would stand out as islands along the north shore, are tied together and so to the main island by these beaches, as in the case of Center island in Oyster Bay harbor, which is thus joined with Oak neck, and that in turn to the land. The upper and inner portions of these beaches are composed of dune sand.

In the narrower bays and creeks behind the barrier beaches marine marshes have developed on both sides of the island. The extent of these deposits on the south side is very much less than on the south coast. The land in such situations usually slopes beneath the inner margin of the marsh flats without evidence of former wave action at this level. Both the beaches and the marshes have developed in post-glacial time. If during all this time the sea stood at its present level, before the barrier beaches were formed the waves must have had a relatively free run against the sides of certain inclosed uncut bay shores of the present time, and would have nipped the incoherent materials so as to form a small but perceptible cut bench and bluff. The absence of this feature in what but for the barrier beaches would be exposed bay shores seems explicable only on the hypothesis that the land has sunk, so that the wave-cut terraces,

[1] For a recent discussion of the origin and terminology of seashore deposits, consult F. P. Gulliver, Shore line topography. Am. acad. arts and sci. Proc. 1899. 34 : 151–258; also F. J. H. Merrill, Barrier beaches of the Atlantic coast, Pop. sci. mo. 1890. 37 : 736–45.

made when there were no barrier beaches, are beneath the present sealevel.[1]

Wherever the breadth of water is sufficient, however, and the depth too great to permit of marsh growth the bay shores are now being cut back in a marked manner by wave action, as at Cooper bluff.

Evidence of local depression of the shore line is found in beds of peat extending outside of the beach below low tide level. Such a bed, containing a flattened log, was exposed in the summer of 1900 at the northeast end of the barrier beach uniting Prospect point with Sands point. Peat was also exposed on the front of the beach at low tide half a mile southeast from Prospect point. In view, however, of the compressibility of the original swamp deposits, these localities can hardly be regarded as proofs of a general sinking of the island.[2]

It is questionable whether even measurable evidence of a slight depression of the shore line along a coast of incoherent and yielding materials such as the clays and gravels of the north coast of Long Island may be taken as evidence of a movement of the continent. There is a slow movement of the loose materials toward the shore in many high bluffs. At Ragged Land point east of Northport harbor this movement in clays has developed a landslide structure, a process which presumably has been continuous since the suggestive name was given to the irregular projection which these clays make on the beach. They move with something like glacial flow, overrunning the normal beach, the wave action being there unequal to the task of maintaining a straight shore line.

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[1] De la Beche appears to have first made this point in the case of certain British beaches. *See* Geological manual. Phil. 1832. p. 73–75.

[2] Suess, Edouard. La face de la terre. Paris 1900. 2 : 670–89.

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GLOSSARY

Terms used in this bulletin or found in writings concerning glacial phenomena

Aggradation, aggrading. Deposition of alluvial plains by streams

Borrow-pit. Pit from which gravel or sand is taken in construction work

Boulder belt. Extended pile of boulders accumulated in the form of a frontal moraine or excessively bouldery ground marking the former position of the front of an ice sheet

Boulder train. Term applied in the United States to the train of boulders and pebbles distributed by the ice sheet over the country southward of some readily identified rock having a limited exposure in the glaciated field and of which the boulders and pebbles consist

Col. That part of a divide which lies in a pass

Columbia formation. Series of loams, gravels, and sands occurring in the coastal plain, forming terraces and river deltas deposited during the submergence of the land before the last or Wisconsin glacial epoch and after the tertiary. The deposits are variously subdivided in New Jersey and Maryland. The coarseness of some of the deposits indicates a period of cold with signs of glaciation and one or more advances of the ice over the glaciated district

Cone. Conical pile of rudely stratified sand and gravel often with included boulders with a fan-shaped outward base, and a steep face toward the position formerly held by the ice front against which it was deposited by outpouring, waste-laden water from the melting ice

Crease. One of the channels formerly held by a stream coursing over the surface of a delta or glacial sand plain and now usually dry for the reason that the water came from the melting ice along the front of which the deposit was built

Cuesta. In physical geography, a land form consisting of a perceptibly inclined plain overlooking a steep slope or escarpment on its higher side, developed by erosion on the retreating outcrop edge of a gently inclined hard stratum

Digitation. Fingerlike branching of the headwater tributaries of streams

Drift. *See* Glacial drift

Drumlin. Lenticular or oval, drum-shaped hill composed of till deposited by an ice sheet; distinguished from a kame by its usually greater size, its elongate oval form, and its composition

Drumlinoid. Having the form of a drumlin

Esker. Long winding ridge of gravel and sand, often associated with glacial sand plains and kames, and considered by most geologists to be the deposit made in the channel of a subglacial stream

Esker-fan. Small glacial sand plain or delta with a lobate outward margin and a terrace, often cuspate, on the inward margin facing the ice sheet against which it was formed at the same time that the associated esker was being deposited inside the ice sheet

Fore-set beds. Cross bedding often on a large scale developed in formation of the subaqueous portion of deltas. Each fore-set bed is an underwater talus formed at the growing edge of the delta where the stream coursing over the surface of the delta drops its load on reaching open water. The beds incline steeply forward in the direction in which the delta is building, hence the name. Fore-set beds are usually overlain by the top-set beds, which see

Fosse. Depression or unfilled area often found between the terraced ice contact of glacial sand plains and morainal mounds forming a belt within the ice covered field, as on Nantucket

Glacial drift. In a general sense, the boulders, till, gravels, sands and clays transported by glaciers or the stream flowing from them; specifically in some writings, unstratified or ice-laid drift. Unmodified, unstratified, or unassorted drift are expressions referring to the till or ice-laid drift; modified, stratified, or assorted drift are expressions applied to the water-laid gravels, sands, and clays produced in the vicinity of melting glaciers or remnant masses of ice

Glacial lobe. One of the lobate protrusions of the margin of an ice sheet, sometimes a score or more miles in width as where the ice has been free to spread out in depressions along its margin

Glacial retreat. A glacier is said to retreat when its front recedes. The ice may be actually moving forward toward this front, but the rate of backward melting at the front, if it exceeds the rate of forward movement, will cause the position of the front to recede

Glacial sand plains. Deposits of stratified gravel and sand in the form of deltas and gently sloping fans, deposited by streams along the margin of a glacier. Where built into open water, the deltas usually show fore-set beds in the body of the deposit and top-set beds capping the whole. Where the deposit has banked up about the margin of the ice front, a terrace is formed by the subsequent melting out of the ice

Glaciated. Said of a country which has been scoured and worn down by glacial action, or strewn with ice-laid drift

Ground moraine. Coating of boulders or mixture of boulders, gravel, sand, and clay which a glacier leaves on the surface of a country. In existing glaciers, the debris carried along under the ice

Ice contact. Terracelike slope at the iceward margin of deposits which have been banked up against the ice front or about masses of ice. The slope is often cast in mounds (kames) and hollows which result from the melting out of buried masses of ice. Where smooth and even like a river terrace, it may be distinguished from a river terrace by its position often being such that a river could not have flowed along its base

Ice-laid. Said of boulders, or mixtures of boulders, gravel, sand, and clay which have accumulated under a moving glacier or have come to rest on the ground from the melting out of the ice in which the material was embedded

Ice sheet. Form of glacier moving radially outward from a region of great snowfall and covering usually all but the highest mountains in its path

Interglacial. Interval between two glacial epochs or advances of the ice

Intraglacial. Said of phenomena peculiar to the field actually covered by the ice at any given time; contrasted with extraglacial

Interlobate. Lying between two lobes of a glacier

Kames. Mounds of stratified or rudely stratified gravel and sand often separated by hollows; due to the irregular settling or deposition of deposits laid down in the presence of melting masses of ice

Kame moraine. Belt of glacial deposits laid down by the interaction of ice and water at or just within the margin of an ice sheet, and having the form of kames

Kamy. Characterized by low knobs and shallow depressions (colloquialism)

Kettle-hole, ice-block hole. Pit or depression sometimes occupied by standing water; often found in glacial sand plains or other glacial deposits where masses of ice have melted out

Lobe. One of the rounded spurs of the outward margin of a delta formed where a stream has pushed its deposit out beyond the general line; also one of the protrusions of ice along the margin of a glacier

Moraine. Swiss term for the debris transported and deposited by glaciers; in America, the ice-laid drift accumulated about the edge of a glacier, usually in belts and often a mile or more in width, classified with regard to position in relation to the ice as frontal, submarginal, lobate, interlobate, etc.

Osar. Swedish term for eskers; Swedish singular os, plural åsar; through misunderstanding, English singular osar, plural osars have been used

Outwash. Said of plains of gravel and sand transported by glacial streams and deposited along the ice front

Overwash. Said of plains of sands and gravels or terraces supposed to have been moraines leveled off by glacial streams along an ice front

Parma. Geologic term used by Suess for a fold in strata lying in advance of the main area of folds in a system of folded rocks

Piedmont. Lying at the base of the mountain; specifically on the Atlantic slope of North America, the belt of ancient rocks of little or moderate relief lying between the coastal plain and the belt of mountainous relief farther inland

Post. Prefixed to the name of a geologic period or epoch to denote any subsequent time

Post-glacial. Time since the disappearance of the great ice sheets of the Pleistocene period; in some writings, the time immediately following the last glacial epoch

Pre. Prefixed to the name of a geologic period or epoch to denote any or all previous geologic time; in a narrow sense, the immediately preceding time or rocks peculiar to that time; as in

Pre-glacial. Term generally intended to refer to phenomena immediately preceding the glacial period; often vaguely used, and in older writings often applied to formations now understood to be of Pleistocene age but older than the last or Wisconsin epoch

Quadrangle. In references to the topographic map of the United States, one of the four-cornered divisions of land corresponding to an atlas sheet; the area mapped as distinguished from the map or atlas sheet

Retreat. *See* Glacial retreat

Roche moutonnée. One of the half rounded smoothed knobs of rock produced by glacial erosion

Run-off. That part of the rainfall which discharges into the streams of a region without passing underground

Sand plain. *See* Glacial sand plains

Striation. Act of scratching the surfaces of ledges and boulders by the movement of glaciers

Striae. Scratches or furrows produced on rock surfaces by glacial action

Tarn. Small lake, as in the glaciated district of Scotland; specifically, a mountain lakelet of glacial origin, a rock basin

Terminal moraine. In North America, the outermost line of moraine made in the last or Wisconsin ice epoch traceable from Nantucket across Marthas Vineyard, Block Island, Long Island, and thence westward over the mainland

Terrane. Any definite portion of the earth's crust defined by its geographic position or its geologic age; as the piedmont terrane, the pre-Pleistocene terrane

Thalweg. Stream channel at the bottom of a valley

Till. In the widest sense, rock debris carried and deposited by the direct action of a glacier; typically, a more or less compact mass of boulders, gravel, with sand or clay, without stratification and necessarily of glacial origin

Top-set beds. Horizontal or gently inclined layers of gravel and sand which form the superficial coating of glacial sand plains or deltas; made by wandering aggrading streams usually at or above the level of the sea or lake in which the delta is building

Water-laid. Said of detritus deposited by water

Wisconsin epoch. Term employed in this report for East Wisconsin, the name proposed by Prof. Chamberlin for the last glacial epoch in the state named; believed to include the time of formation of the later glacial drift in the eastern United States from the terminal moraine northward into Canada

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